Design of Steel Structures

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Module - 6
Flexural Members
Lecture - 2
Design Procedure of Beam Members

Hello today I am going to discuss about the design aspects of flexural member or beam member. Now, when we are talking about designing of beam member different aspects, we have to see 1 is, if beam is unsupported means lateral support is not there, another is if lateral support is there.

For lateral support laterally support and unsupported beam the design philosophy will be different. Because, the compressive stress allowable compressive stress for both the cases will be different; how it is going to differ that we will discuss later. But today we will be focusing our lecture only on the laterally supported beams; that means the beam when it is subjected to transverse load how it is going to develop the stresses. Stresses means stresses due to bending, stresses due to shear and the deflection.

So, when we are going to design the beam what are the things we will check? First we will find out the stresses due to bending and accordingly we will try to find out the appropriate section modulus, and then appropriate dimension of a beam section. And based on the availability of the member and requirement we will choose some particular section, then we will check for shear stress. Shear stress whatever, shear stress is developing that we will check.

Next what we will do? We will check for deflection, because deflection criteria has to be maintained as given in the code which we have discussed last lecture. Next another aspect which we will discuss today is the crippling and buckling effect, because of concentrated load at a particular section of the beam and at the support, where the reaction force is developing in constant way there crippling effect will come into picture.

So, we have to see that the design section whatever section we are going to adapt whether it is for crippling effect point of view or not. That means, the stresses due to crippling we will check and then we will find out whether the member which we are going to adapt is ok or not, so in this way we will try to design right. So, now first we will see what are the aspects of design means, design procedure?

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Design procedure can be divided into 3 parts: one is structural effects; another is secondary effects, then practical limitation. That means, when we are going for designing we will see the structural thing means structural requirements what are the things required. As we know as I was telling that it is required the bending moment; that means, what is the bending moment and because of bending moment what is the stresses say sigma bt or sigma bc, where stresses sigma bt is the bending stresses due to tension and bending stress in compression of the member.

Then shear force and for that what is the shear stress is developing and what is the limiting stress, and then we will find out whether it is ok or not. And then deflection we have to check the deflection maximum deflection what is developing in the hum in the member then we will see whether it is violating the Codal provision or not. And of course, stability because stability is another criteria through which we have to see whether the member is stable or not.

What are the secondary effects? Secondary effects as we know that is local buckling and secondary forces. Local buckling may come into picture other thing is secondary forces, due to buckling it may come into picture, another is connections also we have to see.

And practical limitations also we have to look into matter that is, so durability, fabrication, tolerance and erection, all these things we have to see right.

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Now, beam can be designed in different way there are 2 design philosophy are existing: 1 is working stress method of design, another is limit state method of design. So, here limit state method of limit state design, so as we know I probably I can assume that you know, what is the basic philosophy of working stress method of design and limit state method of design however, I am just discussing little here that is in case of working stress method we know that the it the material obeys the Hooke’s law.

That means, stress and relationship of the material obeys the Hooke’s law; that means, stress varies as strain right. So, Hooke’s law, which tell the stress is proportional due to the strain. So; that means, in case of working stress method we are going to take the value fy up to this, where the maximum strain is going to develop here. After we are not this portion we are not going to consider. Though it can take some more load with some additional strain.

But in our country means, in India so far we have not introduced the limit state method of design in case of steel. In case of concrete design, we are well conversant with the limit state method of design. But in case of steel design we are not using the limit state method of design so far we are using working stress method of design.

So, here what we will see that from this we can see that E is equal to sigma by epsilon means, E is the modulus of elasticity which will become sigma by E. So, this stress strain relationship we will maintain that stress and strain is proportional stress is proportional to the strain. So, this is varying linearly this is linear. These assumptions we are using for working stress method of design.

So, the maximum value of the limiting stress of the particular material we will consider here up to here; where the distribution is linear, where the curve is linear after that we are not going to consider. But as we know in case of limit state method of design we are limiting the in terms of ultimate load, in terms of serviceability and other things right. Basically ultimate load method is what, ultimate method is like this that after certain period also say if I see tar steel this will be something like this and then fail.

So, up to this we are going to take the effect of deflection. So, this will become fy right. But in case of limit working stress method of design we will take up to this right. So, what we are seeing in case of limit state method of design the load carrying capacity will increase with the increase of some deflection. So, deflection also will increase with the increase of load carrying capacity this is what we used to do.

And of course, in case of limit state method of design what we have to ensure that, serviceability condition and other things that whether this that deflection is for from serviceability conditions whether, the occupants will feel discomfort or not all those things we have to check. So, which is called Serviceability method means, service load what will be the service load all these things will come into picture.

However, we are not going into details of those limit state method we will be focusing our lecture; only on working stress method of design. Here you see the members are primarily designed to resist maximum bending moment and checked for shear considerations, and finally detailed against local buckling and fabrication tolerances. So, entire design method will be based on this philosophy right. I am repeating once again that the members are primarily designed to resist the maximum bending moment and checked for shear considerations and finally, detailed against local buckling and fabrication tolerances.

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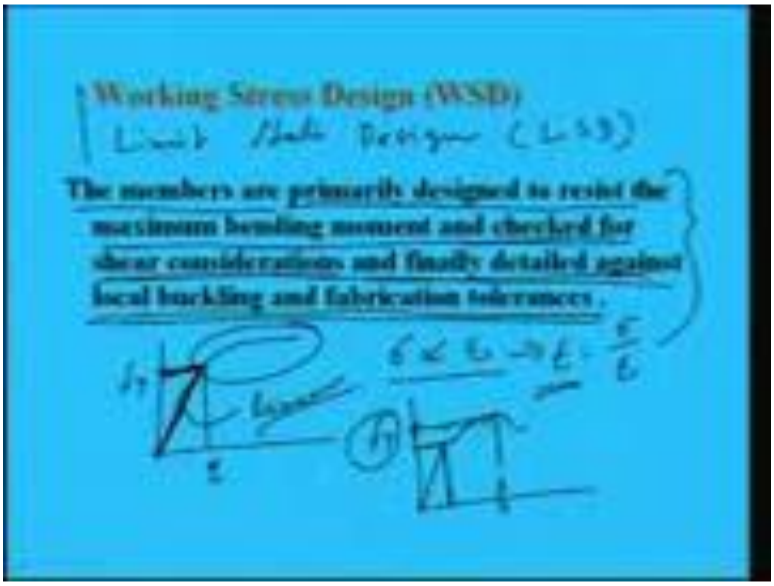

Now, first we will discuss about the criteria for the design of bending moment; that means, if bending moment M develops in the member then how we will reach into the a section a particular dimension of the member; how we will reach that we will try to find out from the bending moment point of view. As we know bending moment we means from bending moment we can find out the bending stress sigma is equal to plus minus M by I into y.

Because, if for a simple case if we see say this is a cross section then we know that the stress will be developed linearly right. Because, working stress method of design we are using. So, we can say that sigma will become M by I into y, and here if we consider the top we can say sigma t and this we can say sigma b. So, sigma t and b will be say plus minus M by I into y, where y is the distance from middle axis right.

So, in this way we can find out sigma is the bending stress. So, we are considering plus in tension and minus in compression or different means or the reverse also we can consider it is up to us how we are going to assume that whether, compression we are going to consider as plus or minus right.

I is the effective moment of inertia of the section and y is the distance of the fibre from the CG where stress is computed. Means, if we compute the stress here then say suppose we have computed stress here; the in this section then we will consider y is this like this.

And then this has to be less than the allowable bending stress right. So, bending stress whatever we are going to calculate that has to be less than allowable bending stress right.

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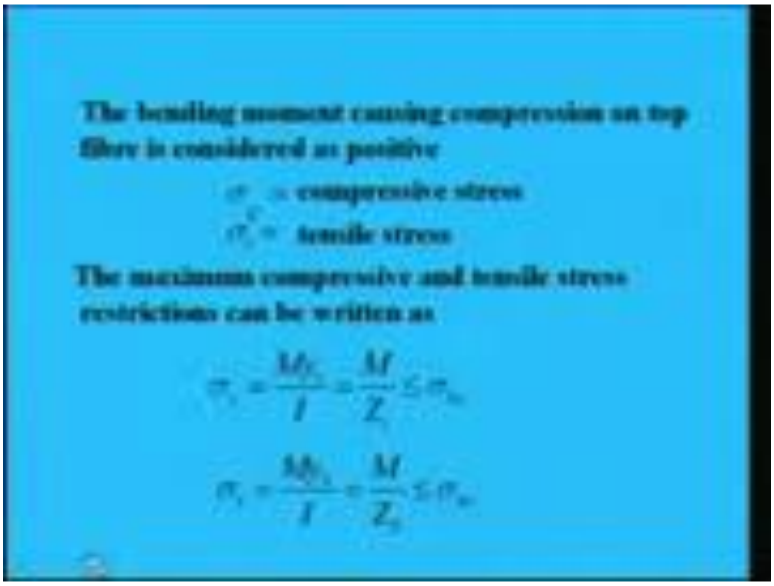

Now, as we are telling that calculated compressive stress we can say sigma c and tensile stress is sigma t. So, sigma c I can write M by I into yt; that means, say if cross section is like this means, stress distribution is like this then here we can assume that this is sigma c compression and this is sigma t it is developing sigma t right. And say this distance is say yt a top flange and this is say yb distance at bottom flange right.

So, this is a member right neutral axis is here. So, what we are calculating that sigma c will become here as M by I into yt right and I by yt can be written as Zt. So, M by Zt and it has to be less than sigma bc, where sigma bc is the allowable bending stress in compression. Similarly, sigma bt will be the allowable bending stress in tension right. And calculated stress bending stress in tension will become M by I into yb; that means, M by Zb which should be less than or equal to sigma bt.

Now, this at the bottom we are considering as tension and at the top we are considering as compression. Assuming that suppose, a beam is like this moment is developing like this then here it is moment is developing like this. Now, if it is buckle like this, so at the bottom it will develop at the bottom it will develop tensile force and at the top side it will develop the compression force right.

So, what we have seen that here we are means the section is undergoing under compression and here it is undergoing under tension. However, it is not always true because it depends on the type of moment what type of moment is going to develop at that section. On that basis the stresses whether it will be in tension or in compressions; bending stress in tension or bending stress in compression that will be depending on the type of bending at that particular section.

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Now, as I was telling yt is nothing but the distance of extreme top fibre. And similarly yb is distance of extreme bottom fibre. Zt we can write that section modulus with respect to top fibre, which is can be written as I by yt. Similarly, Zb is equal to section modulus with respect to bottom fibre which will become I by yb. And sigma bc is the allowable compressive stress and sigma bt is the allowable bending tensile stress right; allowable bending compressive stress and allowable bending tensile stress. So, these are the things means parameters which we know from which we can find out the sigma c means compressive stress and sigma t, right.

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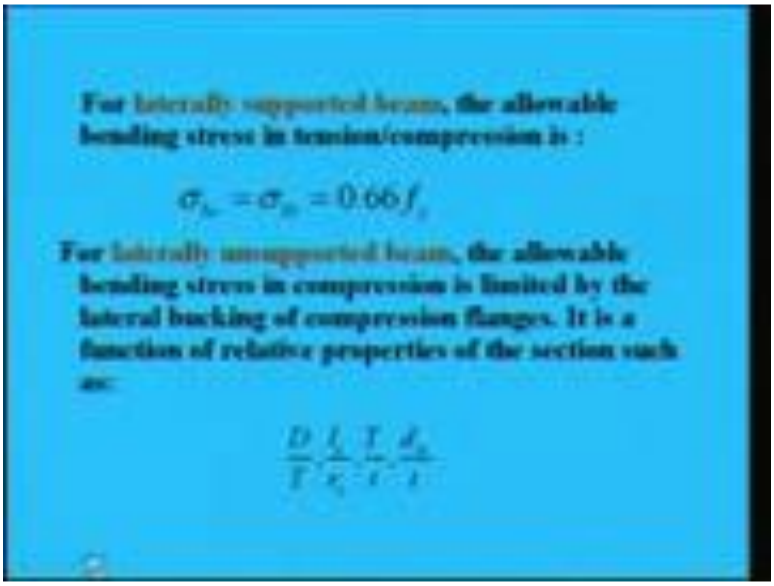

Now, the for laterally supported beam, the allowable bending stress in tension and in compression is equal that is: sigma bc equal to sigma bt which will be equal to 0.66 into fy. So, for laterally supported beam remember. For laterally supported beam, as per the Codal provisions the sigma bc and sigma bt will be equal to 0.66 fy, where sigma bc and sigma bt are the allowable bending stress in tension and in compression right.

So, in this way we can find out the value if we know the grade of steel which we are going to use right. And for laterally unsupported beam, the allowable bending stress in compression is limited by the lateral buckling of compression flanges. It is a function of relative properties of the section such as D by T le by ry then T by t ratio and dw by t ratio these parameters I coming later.

So, what I am seeing here that in case of laterally supported beam the sigma bt will become simply 0.66 fy. But sigma bc will be function of some parameters right, those parameters are d by t ratio le by ry ratio T by t ratio and dw by t ratio. So, this is the difference which we will get for laterally supported and laterally unsupported beam. However, here we will focus only today lecture, we will focus only on laterally supported beam.

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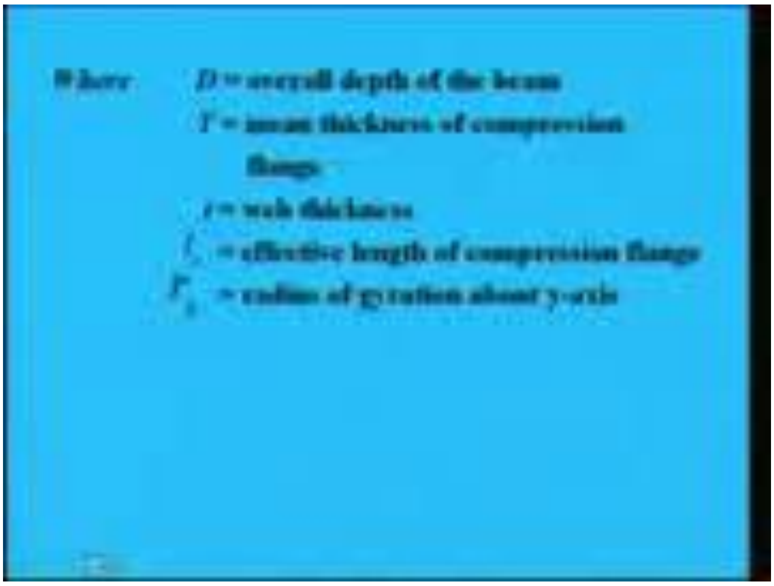

Here you see as I was telling what is DT T t all these things let us see. Suppose, if it is a I section then say what we can do now this is D, where D is the overall depth of the beam. So, D is this which is required to know for calculating the allowable compressive stress, due to bending in the unsupported beam right. T is the mean thickness of compression flange, so if this is the compression zone then this will be T.

So, sometimes this also can become T if compression flange developing at the bottom. So, in this case if compression zone is this 1 then we can write that T is equal to this width that, the mean thickness of compression flange. And then t is the web thickness this is called t and le is the effective length of compression flange. And ry is the radius of gyration about y-axis.

If this is yy then we can say and if this is xx, then ry is the radius of gyration about y-axis right. So, from these parameters we can find out the values of this D by T ratio, where D is the overall depth T is the average thickness of the compression flange le by r ratio ry ratio this also we know T by t ratio and dw by t ratio we can find out, dw will be depth of the web.

So, in this way we can find out those ratio and from that ratio we can find out the allowable compressive stress, due to bending sigma bc for laterally unsupported beam., so in this way we can find out. Now, how do we find out some derivation is there which we will discuss in next class. In IS: 800 1984 steel design code there we will get the value of sigma bc for different ratio of D by T and other things right. But those values have been calculated from some expression which also we will show in next class.

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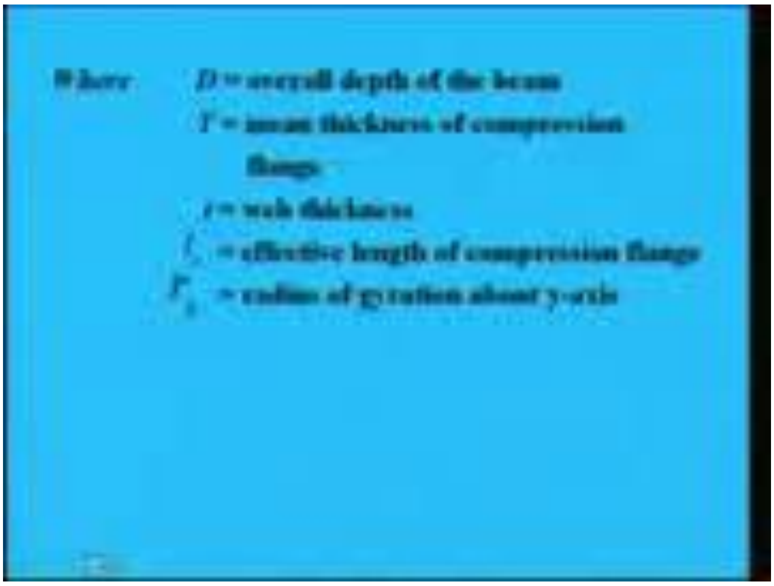

Now, to calculate these things 1 important thing is required that is effective length of compressive flange. So, in clause 6.6.1 of IS: 800 it has defined, how to calculate the effective length that has been specified in clause 6.6.1 of IS: 800, 1984 what it is told that, for simply supported beam and girder where no lateral restraint of compressive flange is provided, but where each end of the beam is restrained against torsion, the effective length l of the compression flanges shall be taken as follows.

That means, when a simply supported beam or girder where no lateral restraint of compressive flange is provided and where each end of the beam is restrained against torsion, the effective length can be taken as follows which is given in the code.

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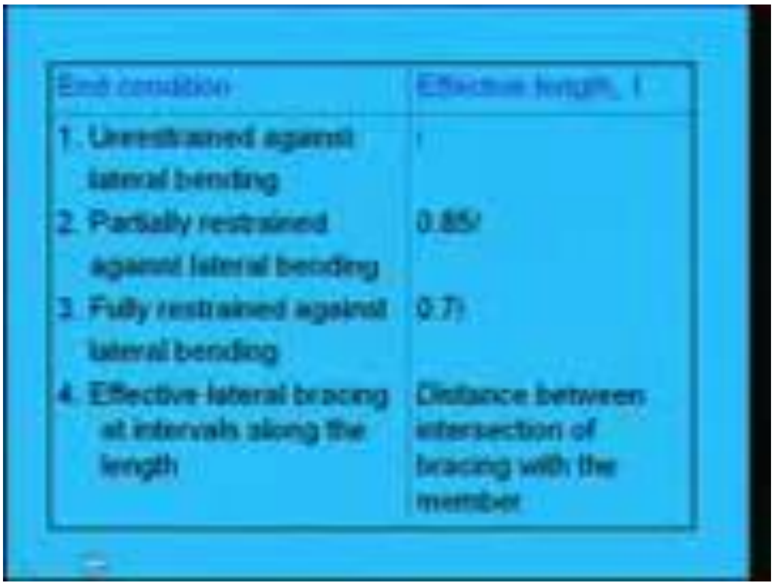

That is with different some end conditions the effective length has been defined in the code right. That is say suppose in case of unrestrained against lateral bending, if it is unrestrained against lateral bending then effective length can be taken as l; that means, the clear span the span length right. And if it is partially restrained against lateral bending, then this can be taken as 0.85 l right. If the end condition is partially restrained against lateral bending then we can consider as 0.85 l.

Remember this is for the simply supported beam and girder where no lateral restraints or compressive flange is provided, but where each end of the beam is restrained right. So, against torsion third case is fully restrained against lateral bending that will be considered as 0.7l. And if effective lateral bracing at intervals along the length is provided, then the effective length will become distance between intersection of bracing with the member. In fact, this has given in the code which can be looked later by the readers.

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Again where the ends of the beam are not restrained against rotation against torsion or where the load is applied to the compression flange and both the load and the flange are free to move to laterally, the above values of the effective length shall be increased by 20 percent. So, above values of the effective length can be increased 20 percent; that means, 1.2 into le. Whatever, le value we are getting from the table earlier that can be increased up to 1.2l.

When let me again reiterate that is where the ends of the beam are not restrained against torsion or where the load is applied to the compression flange and both the load and the flange are free to move laterally, the above values of the effective length shall be increased by 20 percent right. So, that has to be taken care while calculating the effective length.

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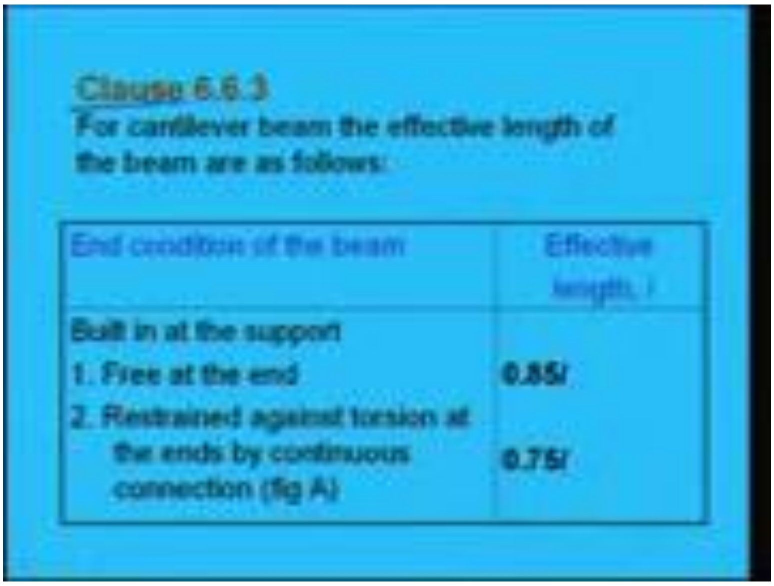

Now, in clause 6.6.3 it is told that for cantilever beam the effective length of the beam as follows. For if we consider the cantilever beam then effective length will be as given in the table. Now, for different end condition of the beam the effective length has been considered say in case of built in at the support with free at the end will become 0.85l. Again with restrained against torsion at the ends by continuous connection in that case we will consider the effective length as 0.75l. So, in this way we can find out the effective length.

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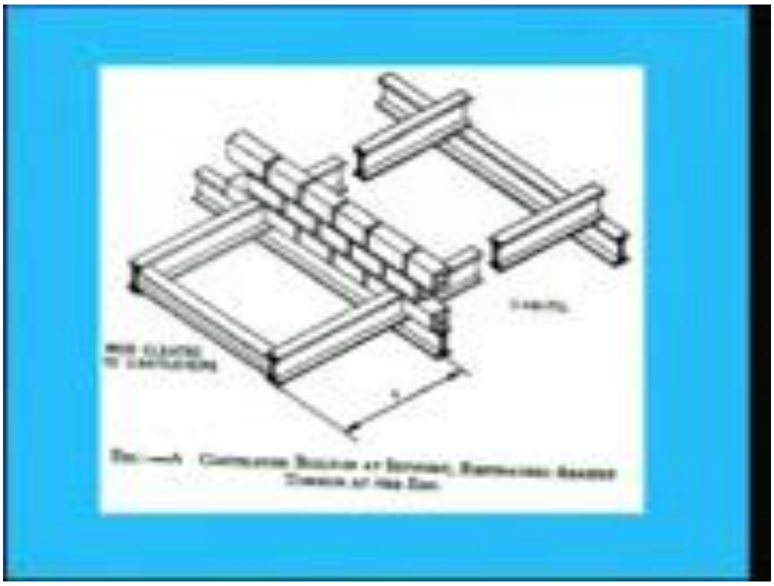

Now, this connection has been shown in figure A, in the Codal provision you will see this is the type of connection which has been made that cantilever built in at support restrained against torsion at the end. So, in this case the effective length will become 0.75l.

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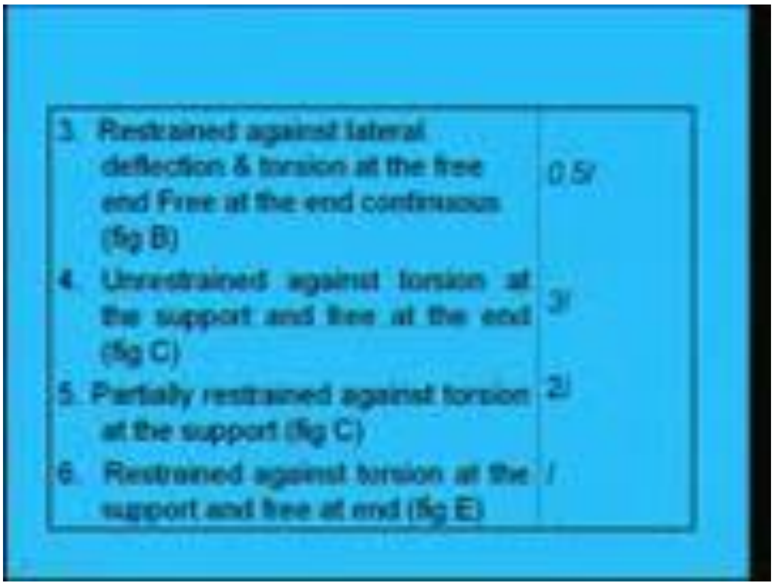

3. Restrained against lateral deflection & torsion at the free end Free at the end continuous (fig B)	0.5l
4. Unrestrained against torsion at the support and free at the end (fig C)	3l
5. Partially restrained against torsion at the support (fig C)	2l
6. Restrained against torsion at the support and free at end (fig E)	l

Now, in third case the end condition is like this that, restrained against lateral deflection and torsion at the free end at the end continuous figure B that will be 0.5l.

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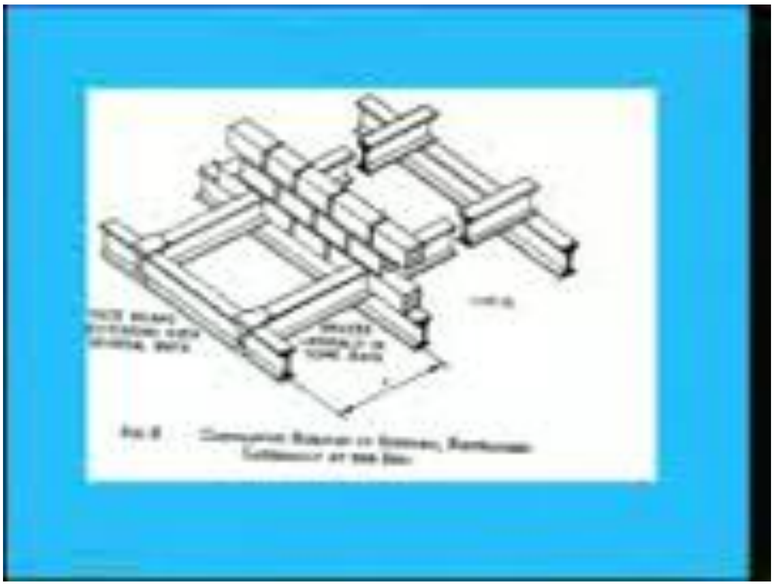

So, in figure B you see this length will become effective length will become 0.5 into L right. Cantilever built in at support restrained laterally at the end. So, in this case the effective length will be this. Again, where unrestrained against torsion at the support and free at the end unrestrained against torsion at the support and free at the end.

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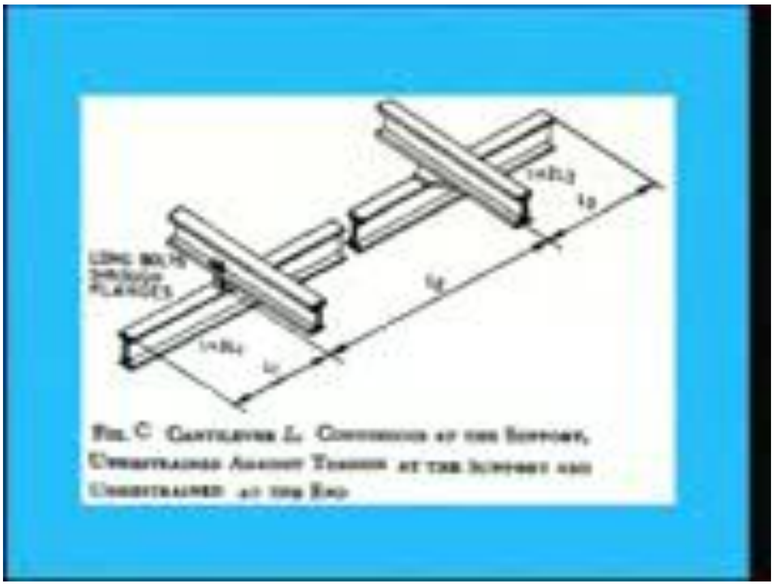

In this case in figure C it is shown that the l will become like this right. So, if L1 is this L2 is this and L3 is this, so L will become 2L3 and here l will become 3L1 so 3 times it will right. So, 3 times unrestrained against torsion at the support and free at the end in this case this will be 3L. And partially restrained against torsion at the support in that case it will be 2L which has been given here.

See in this case it will be 2L and in this case it will be 3L right. So, for different end condition of the cantilever beam the effective length has been calculated in different way. And number 6 condition is, restrained against torsion at the support and free at end which is given in figure E that is this 1.

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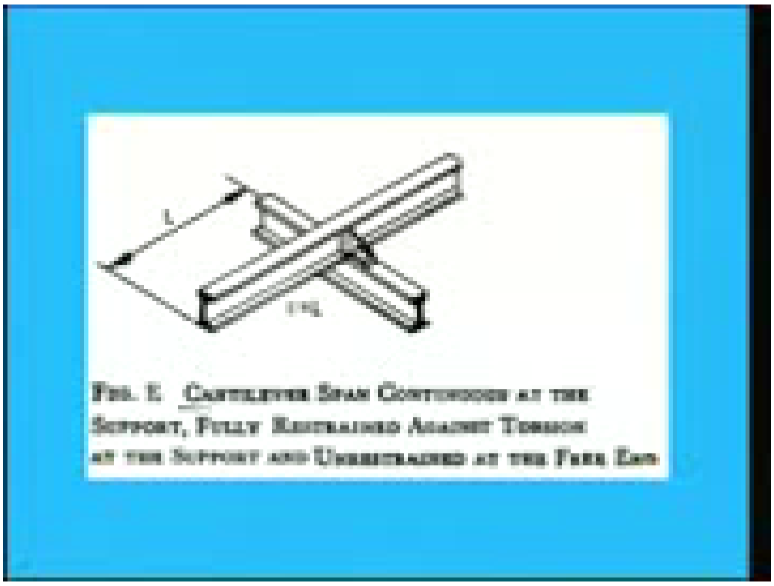

Cantilever span continuous at the support, fully restrained against torsion at the support and unrestrained at the free end. In this case effective length will become equal to l. So, these are the some conditions where Codal provision has been given and through that, we have to find out the effective length for calculating the sigma bc.

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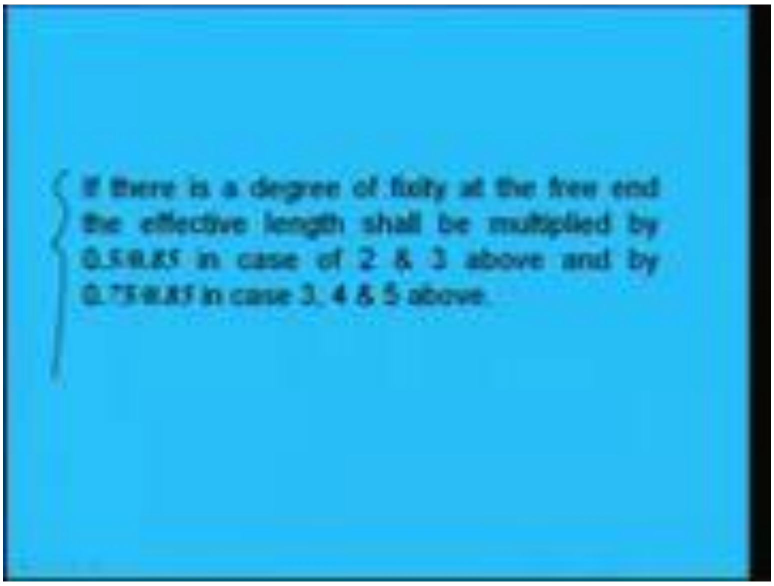

Another thing is told in the code that is, if there is a degree of fixity at the free end the effective length shall be multiplied by 0.5 by 0.85 with this ratio in case of 2 and 3 above and by 0.7 by 0.85 in case of 3, 4 and 5. So, the cases 1 to 6 we have discussed in case of

2 and 3 we can multiply by 0.5 by 0.85. And in case of 4, 5, 6 this will be 4, 5, 6 it will be 0.75 by 0.85.

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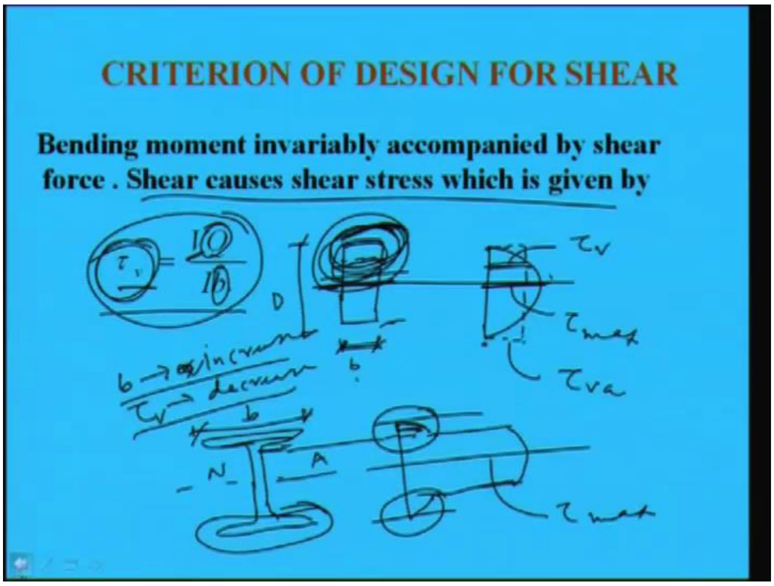

Now, we will discuss about some criteria to find out the shear stress and the design value of the shear stress right. As I told that first step is to find out the appropriate section of the beam from the bending stress point of view. Now, what we will do we will try to find out the what is the shear stress developing for that particular section and what is the allowable stress allowable shear stress of that section.

Then, we have to see whether the developed stress is less than the allowable shear stress or not. If it is less than then fine it is otherwise, you have to increase the dimension of the section. In case of shear what we will do that we know that the shear stress developed in the section can be find out by this formula. That is tau v is equal to VQ by Ib. How it develops?

Suppose, if we have a rectangular section right with say width as b and this is say D, then we can find out the shear stress that will develop parabolically like this. This is the maximum tau max which is developing say in this say in this line the shear stress will develop this 1 which is called say tau V right; tau V is the developed shear stress. And average shear stress can be found from here; that means, with equivalent design if we make this will be tau va, so this is called tau va.

And tau max will develop at the neutral axis means at the middle means during and at the cg or somewhere else means, at the middle basically in this case and it will be 0 at the end right, so in this way we can find out. And tau v can be expressed from this equation. Now, you see this tau v is the shear stress developed is a function of not only shear force VQ by Ib it is a function of VQ I and b; b is the width of the member.

Now, if we increase the b then what will happen we will see the tau v is decreasing; that means if we increase the value of b, if we increase tau v will decrease. So, we have to try to increase the value of b at particular position, so that tau v becomes less. Suppose in case of I section how it develops tau v let us see. So, this is an I section, so this is the neutral axis now if we see we will see. Now, in this case VQ by Iv now it will start from 0 and Ib here b is this 1 right.

So, this will become something like this then suddenly it will jump here at this right. So, because b is reducing, so it will jump here and then it will develop like this right. So, shear stress tau v will be developing like this; this is the maximum tau; tau max. Here it is important to note that, this portion is very less shear stress is very less , because here b width of the section is very high. And sudden jump of mean, sudden decrease of width at this position is going to increase of shear stress suddenly. So, this is how it develops, so we have to take care all these things. Here what are the parameters VQ by Ib as we know,

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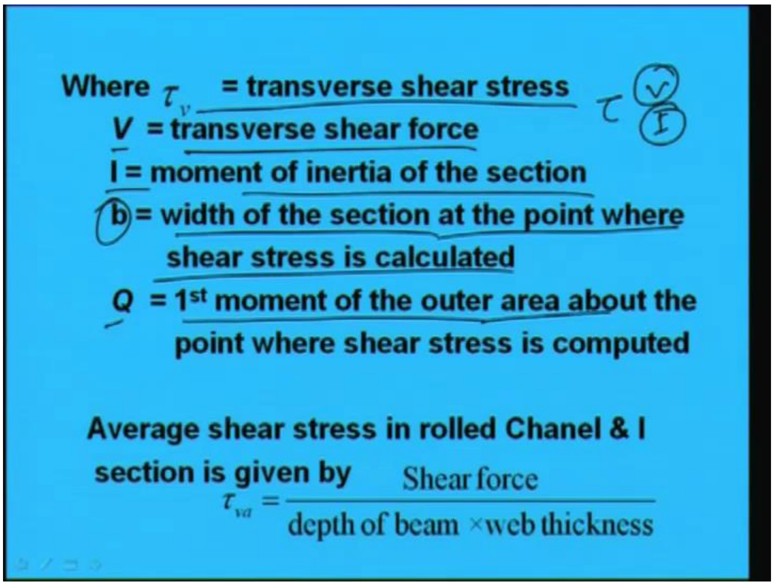

The b we have told already that width of the section at the point where shear stress is calculated. If we are calculating shear stress here then we have to calculate the b here. And other thing is V; V is the transverse shear force which can be calculated from the loading condition. And tau v is the transverse shear stress means, due to the shear force developed. An I is the moment of inertia of the section I we can find out. So, what we have seen in case of developing tau v; v is constant for a particular section, I is constant right varying only b and Q. What is Q? Q is the first moment of the outer area about the point where shear stress is computed remember.

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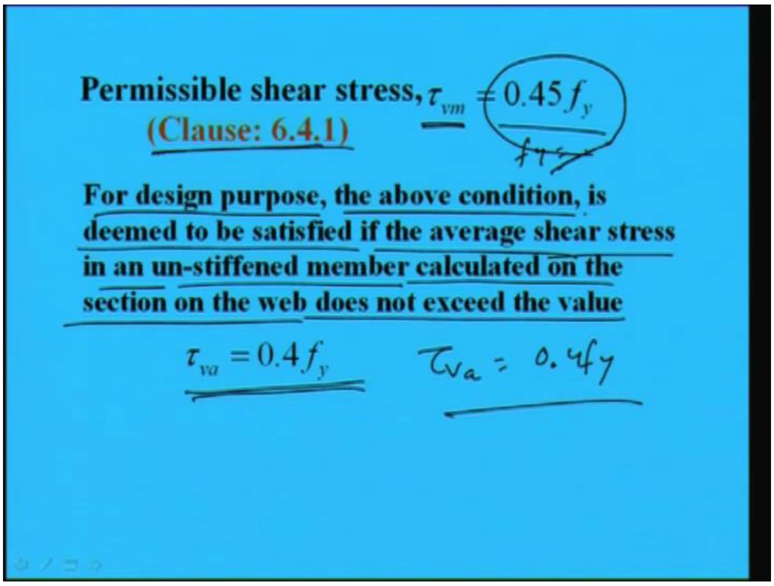

Suppose we are computing the shear stress suppose here;, so first moment of the outer area, so from here we can find out right. So, in this way Q value can be find out. Now, you see the moment you are increasing the value of means, where value of Q then tau v will be increasing; that means, if you go below from the extreme fibre or go up from the extreme bottom fibre then this area will become more.

So, outer fibre means outer section area will become more means, this Q will become more; that means tau v will be becoming more that is why maximum stress is developing at the center right. Where the maximum area of the sections we will get from outer distribution right. That is why we have to remember that Q is first moment of the outer area about the point, where shear stress is computed right.

So, in this way i can find out tau v tau v is the developed shear stress. Now, average shear stress in rolled channel and I section can be found from this equation that is average shear stress is shear force by depth of beam into web thickness. That means, some average shear stress for channel section and for I section can be found out simply from this equation right. Or we have seen that how to find out the tau v average shear stress that equivalent we have to make right.

Now, as per the clause 6.4.1 what it is told in IS: 800 clause 6.4.1 that permissible shear stress tau vm is equal to 0.45 fy, where fy is the yield stress; that means, for different grade of steel fy will be different. So, say suppose we are using fe 250, so fy will become 250 right.

So, on that basis we can find out the permissible shear stress tau vm. Again for design purpose the above condition is deemed to be satisfied, if the average shear stress in an un-stiffened member calculated on the section, on the web does not exceed the value of this. That means, simply we can calculate tau va is equal to 0.4 fy right and it should not exceed this value. So, average shear stress should not exceed the value of 0.4 into fy.

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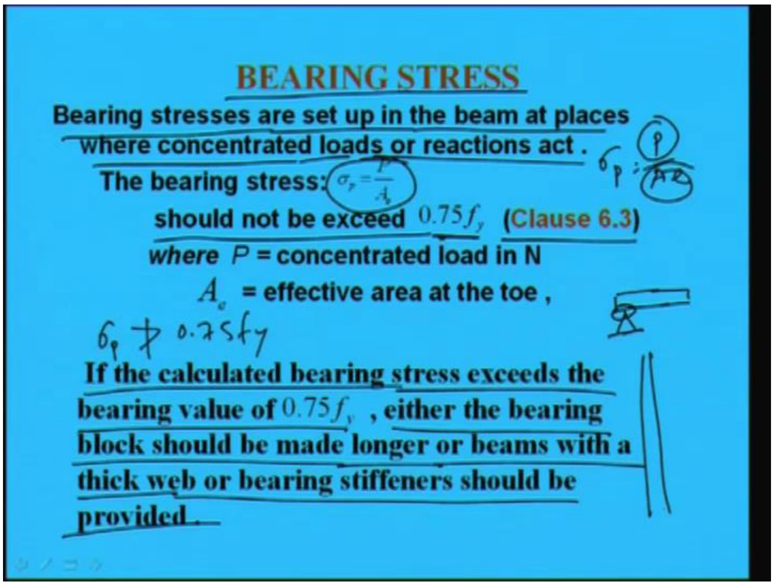

Another aspect is the bearing stress; bearing stress where it develops as we know where the concentrated load is there or where the support is there suppose simply support is there. So, the stress will develop here some, because of concentrating force in nature the stress will develop. So, bearing stresses are set up in the beam at places where concentrated loads or reactions act right.

And that can be find out from this equation: sigma P is equal to P by Ae, where P is the concentrated load in Newton right. And Ae is the effective area at the toe; Ae is called effective area at the toe and P is the concentrated load in Newton. And this bearing stress should not exceed 0.75 fy this bearing stress sigma P should not be greater than 0.75 fy. And this is defined in code IS: 800 1984 in clause 6.3.

So, regarding bearing stress in clause 6.3 of IS: 800 it is told that the bearing stress whatever it is developing it has to be less than 0.75 fy that also we have to keep in check right. So, if the calculated bearing stress exceeds the bearing value of 0.75 then what we will do? Either the bearing block should be made longer or beams with a thick web or bearing stiffness should be provided. So, possible remedies which we can do that either we can use the bearing block or beams with a thick web or bearing stiffness that we have to provide. So, in this way we can match we can make the beam safe right. So, from bearing stresses point of view we have to check this 1.

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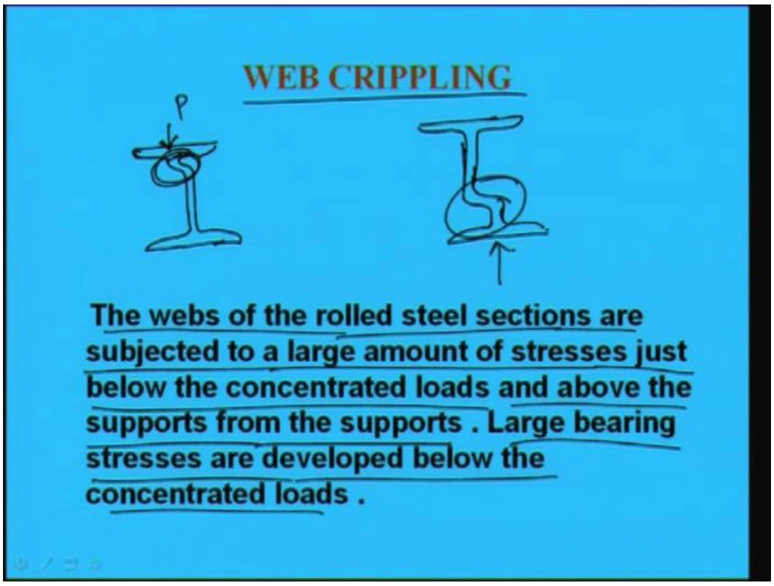

Another important aspect of the design of beam has is, the web crippling means we have to see whether the beam whatever we have designed is safe against the crippling effect or not. So, what is the web crippling let us see first that if say suppose say concentrated load is there say we are making an I section right. So, if it happens like this; that means, because of concentrated load here say P here it is buckling means crippling right.

So, the webs of the rolled steel sections are subjected to a large amount of stresses just below the concentrated loads and above the supports. Large bearing stresses are developed below the concentrated loads. So, the because of the large bearing stresses developed at the support and below the concentrated load. So, chances of web crippling will be there, say in case of support how it will look means how it develop.

So, if support is bottom then say this will develop like this something like this right. So, web crippling will develop here; if we have support here right. Now, we have to design the beam in such a way that this web crippling can be restrained right.

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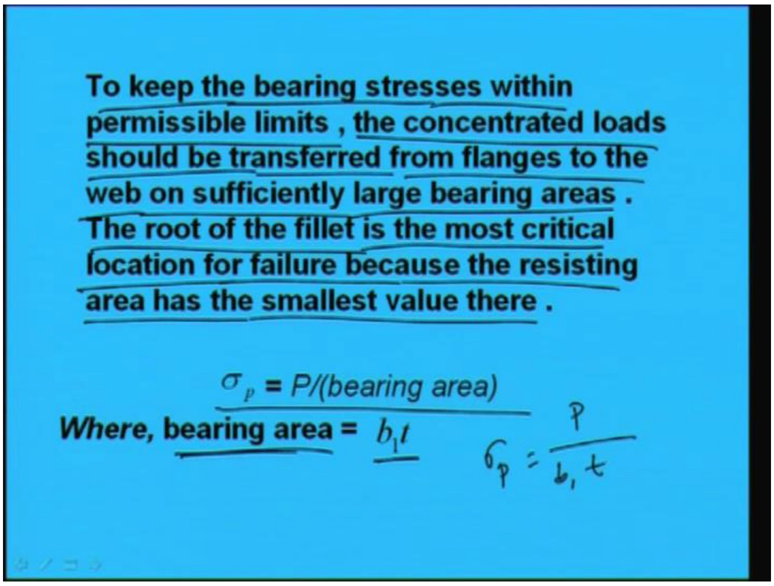

So, to keep the bearing stresses within permissible limits, the concentrated load should be transferred from flanges to the web on sufficiently large bearing areas. The root of the fillet is the most critical location for failure, because the resisting area has the smallest value there. As the resisting area is becoming less, so chances of failure will be there.

So, the bearing stress we can find out from this sigma P is equal to P by bearing area. Where, bearing area can be calculated from this b1 into t. That means, sigma P will become P by b1 into t right. Now, what is b1 and what is t I am coming later.

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So, first let me draw the diagram from which I can find out the value of b1 and t. So, if we see the plate this is at the support now, if support is here we are going to provide say bearing here with a width of b and here it is acting the load P right. Similarly, if the concentrated load is here with a bearing plate of b with a load P right now, it is assumed that the angle of dispersion of load will be 30 degree.

So, these are the assumptions we made right; that means, this is 30 degree and this is 30 degree. So, if angle of dispersion is like this then I can find out this value which is termed as b1 right. Similarly, in this support what will happen angle of dispersion will be only in this reaction with 30 degree angle. So, this will become b1 right and the section is say suppose I section we are considering, so this will look like this right.

So, this is the thickness of the flange say may be h2 right and say this is h and this is the depth of the web. So, I can write d1 and the total depth or overall depth of the beam is d right. So, we are assuming that the load is dispersing at a 30 degree angle. So, what we can find out the bearing length, bearing length b1 this can be find out for this case say this will be b plus this much.

That means b plus this much this much means, if this is h2 as told here then this is h2. So, this is 30 degree so this will become h2 into root 3. So, in 2 places it is there, so 2h2 root 3 this is under concentrated load. So, under concentrated load we are finding out bearing length b1 as b plus 2h2 root 3. Why it is required? Because to calculate this value b1 t right to find out the bearing value, right. Another is bearing length b1 under means at support how much it will be bearing length b1 at support b1 will become b plus h2 root 3. Because here, only angle of dispersion is here, so b1 will be this much; here there is no scope to disperse. So, in this case bearing length is becoming b plus h2 root 3 right.

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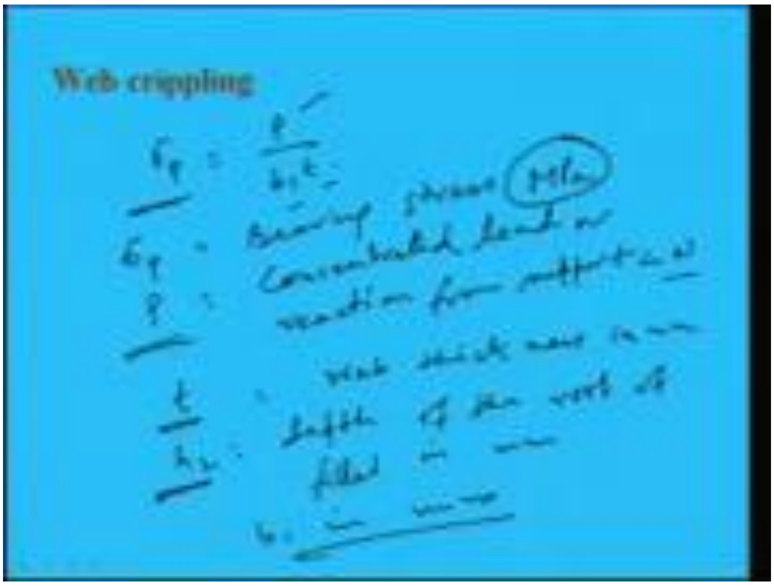

Now, here we can say that sigma P which we are going to develop P by b1 into t. So, sigma P we can write that bearing stress right. And say this can be find out in MPa, if P is the concentrated load or reaction in case of support it will be reaction from support in Newton right. And then b1 we have now, t t is the web thickness in millimeter. So, this is Newton and this is millimeter, this is millimeter.

So, we can find out the bearing stress and h2 is the depth of the root of fillet in millimeter. So, we have to put the value in millimeter here h2 t. So, that we can find out b1 also in millimeter we can find out. And then if P is given in Newton, so we can find out sigma P as MPa. Remember chances of mistake will be there, if we mismatch the unit has to be in same order.

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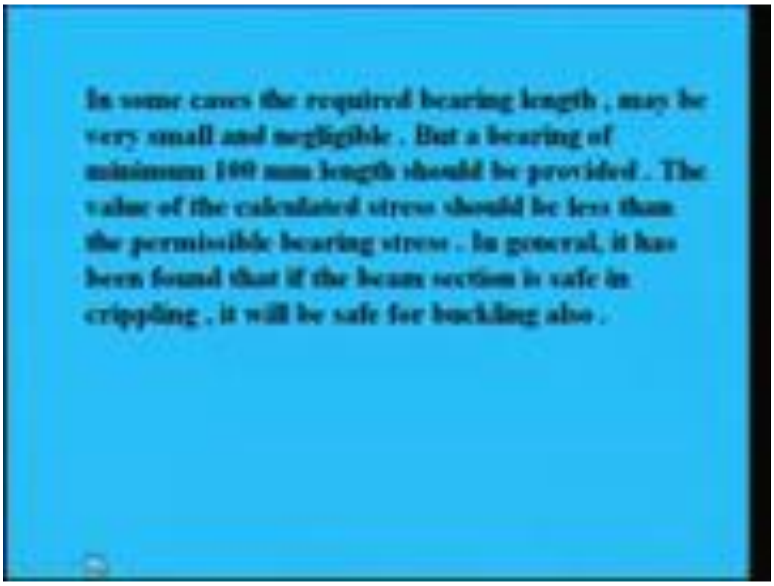

Again whatever we are calculating the bearing length, that may be negligible or very small. Sometimes it may be very small means; in some cases the required bearing length may be very small and negligible. But in this case, a bearing of minimum 100 mm length should be provided. So, in any case we should provide a minimum of 100 mm length of bearing should be provided.

The value of the calculated stress should be less than the permissible bearing stress; permissible bearing stress we have shown. So, in general it has been found that if the beam section is safe in crippling, it will be safe for buckling right. When we are checking the crippling stresses means, if it is safe for crippling then for buckling also it will be safe will be safe in general. But we cannot make it means, for all the cases we have to check.

Buckling things I will come in next class in details how buckling effect has been considered, how the stresses has to be calculated and how the load is coming into picture, due to buckling all these things we will discuss later right. So, what we have seen that a minimum bearing length of 100 mm has to be provided, if the calculated bearing length becomes less with that we can go for design.

Because, in case of concentrated load or at the support the chances of web crippling will be there , because web thickness is generally become very less in case of steel member. We have seen I section, we have seen channel section; we have seen other sort of section, which we really using. So, on those cases sudden jump of width from web to flange is there, so there chances of crippling will be there So, to restrict those things we have to check whether the bearing stress whatever it is developing is capable of taking the load or not.

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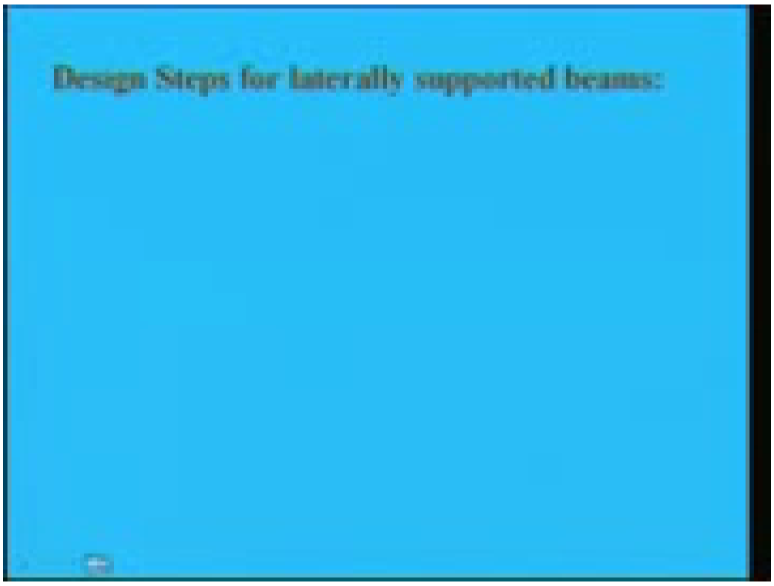

Now, we will discuss the design steps for laterally supported beam. As I told that today we will be focusing our lectures on laterally supported beams. So, whatever we have discussed so far let us make it in step by step. So, that when you will go for 1 workout example will be easily you can do. So, what are the steps what will be the step at the beginning.

So, let us make step say 1 right, so here what we will make let us, say calculate the expected load on a beam. That means, we have to find out what is the load coming into picture on a beam. Load means, imposed load, dead load and including the self weight. All those load has to be calculated then we have to see what are the load is coming. And accordingly in next step what we will do we will find out what is the maximum bending moment and shear force.

So, in step 2 calculate maximum bending moment and shear force. The moment we are calculating the maximum bending moment and shear force, then we can find out the stresses, stresses due to moment. So, this maximum bending moment and shear force can be find out from the loading condition and from the boundary condition of the beam. So, from there we can find out. So, in step 3 we can find out that calculate section modulus required for the load and choose a suitable section from SP: 6 we can find out So, how do I calculate the section modulus as you know.

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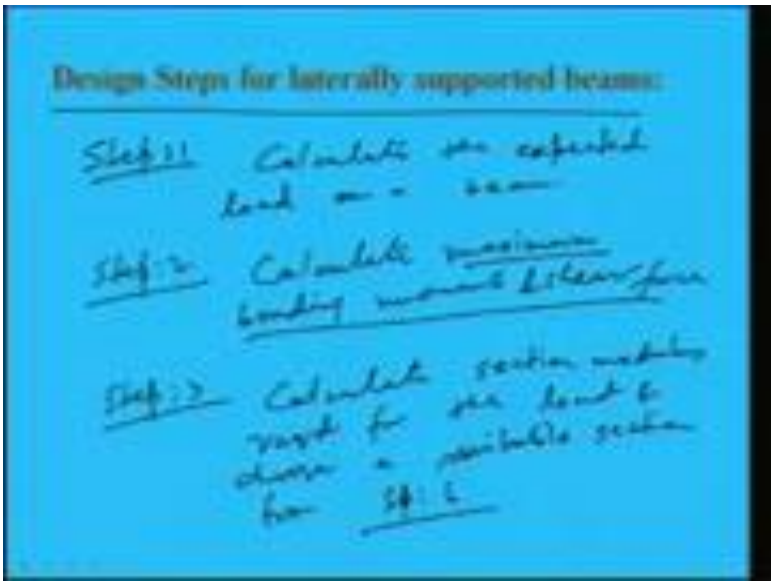

The section modulus z can be written as M by sigma bc or sigma bt right, here sigma bc and sigma bt is same which is 0.66 fy. So, from this I can find out then what is the section modulus is required. And the moment we find out section modulus this is required then we can see what are the available sections which is closer to the required section modulus. Then, we can choose some a suitable section.

First we have to decide what are the availability of the section, whether it is I section is available or channel section is available or some other section is available, on the basis of availability we can find out a suitable section. If nothing is given as we know the most efficient section for bending consideration point of view is the I section. So, we can provide some I section which, where we can find out the closer value of z section modulus. And the choosing means, the required z should be less than the applied z whatever we are applying, whatever we are choosing, that should be little higher than the required 1.

Now, step 4 that is check for shear right, so I know that average shear stress can be developed from this formula V by D into t and which should be less than 0.4 fy, where t is the web thickness and D is the overall depth of section. So, in this way we can find out and in step 5, in next step what we will do check for deflection.

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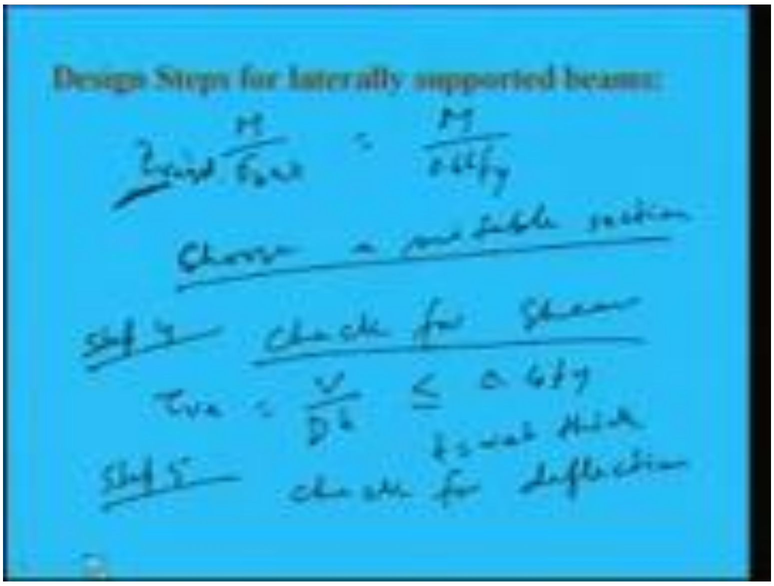

So, as we know in last class we have shown check for deflection means, we have to see what are deflection is coming that should not be greater than span by 325. That means, le by 2 3 25 span means effective length by 325. So, the calculated delta deflection should not be greater than this that we have to check. So, how do we calculate the delta?

That we know we have shown earlier that, for standard beam with standard loading condition with some boundary condition we have seen that how delta is means that kl how the coefficient of deflection has been given. So, directly either from there or from calculation we have to find out what is the maximum deflection happening in the beam and that we have to check whether this maximum deflection is more than the limiting deflection that is span by 325.

If it is more than we have to redesign otherwise it is ok. Next step is check for crippling step 6 check for crippling right. So, here what we will do we will find out sigma P is equal means, it should be less than 0.75 or equal to fy means allowable stress will become 0.75 fy. So, developed stress bearing stress sigma P should be less than 0.75 fy.

Where, sigma P can be calculated from this formula that is P by b plus 2 h2 into root 3 into t for concentrated load right. And this will become P by b plus h2 root 3 into t at support. So, we will calculate the bearing stress developed at the support and at the concentrated load if concentrated load is there.

Then, we can find out what is the bearing stress is developing and whether it is less than 0.75 fy or not. If it is less than 0.75, it is ok, otherwise we have to again redesign. And from this we can find out the value of b b1 the bearing length right. So, in this way step by step we have to check and we can design a beam.

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Now, we will go through 1 example, today I will give the example means I will write down the example here; you try to do at your own time and in next class I will solve the problem and we will see whether it is matching with your workout example or not. A simply supported steel joist with a 5 meter effective span carries a uniformly distributed load of 50 kilo Newton over its span inclusive of self weight right, 50 kilometer per meter over a span inclusive this.

The beam is supported laterally throughout. Select a suitable section and check its safety. That means, we will try to design a beam which has span length of 5 meter; that means, the effective length is 5 meter right. And a uniformly distributed load UDL that is I can write w right. So, that will become say 50 kilo Newton per meter.

So, these are the 2 things has been given, which including self weight. We are assuming that total load is coming 50 kilo Newton per meter which includes self weight, dead load and other things. And this is a simply supported steel joist, so it is like this simply supported steel joist right.

So, this has a UDL load of w is equal to 50 kilo Newton per meter. And of course, the effect length has been given le is equal to 5 meter. So, now we have to design the section; that means, what we will do here yes. Another thing is the fy value the grade of steel we are going to consider is as fy is equal to 250. Because, unless we know the stress; the permissible stress of the steel we cannot find out means, type of steel we have to know accordingly the stresses will be developing.

So, where fy here it is given 250 Newton per millimeter square. So, first we will try to find out what is the bending moment means, maximum bending moment. In case of simply supported beam what will be the maximum bending moment? That will be wa square by 8 right. So, maximum bending moment we will find out then we will find out the maximum shear force which is coming at the support.

Then, what we will do then we will find out the appropriate section on the basis of section modulus. First we will find out section modulus and as it is told that supported laterally throughout. So, sigma bc will be equal to sigma bt which is equal to 0.66 fy. So, from that we can find out. Next what we will do, that appropriate section on the basis of required section modulus we will find out.

After that we will check for shear right. So, maximum shear stress we will find out from that we will find out whether, it is from the developed shear stress point of view. Then, we will go for deflection how much deflection is happening due to this moment and what is the limiting displacement. If it is not ok we have to increase a section if it is ok fine. Then, we will go for check for crippling means crippling effect we will see whether, it is ok or not from the bearing length and other things.

If it is ok fine otherwise, we have to change the section. So, in this way step by step we will check. So, first we will find out on the basis of stress due to bending from that, we will first find out an appropriate section then we will go on checking 1 by 1 shear, deflection and crippling. And after checking all the things, it will be selected that particular section then accordingly we will do right.

So, I hope you can do these things properly and let us do and next day I will work out this example and use I section. So, that the answer will become same for whatever you are doing and whatever I am doing will become same, let us use I section only here. So, with this I will have to conclude here, tomorrow we will discuss about the buckling effect and other things. First we will go through this example then we will do other things.

Thank you very much.